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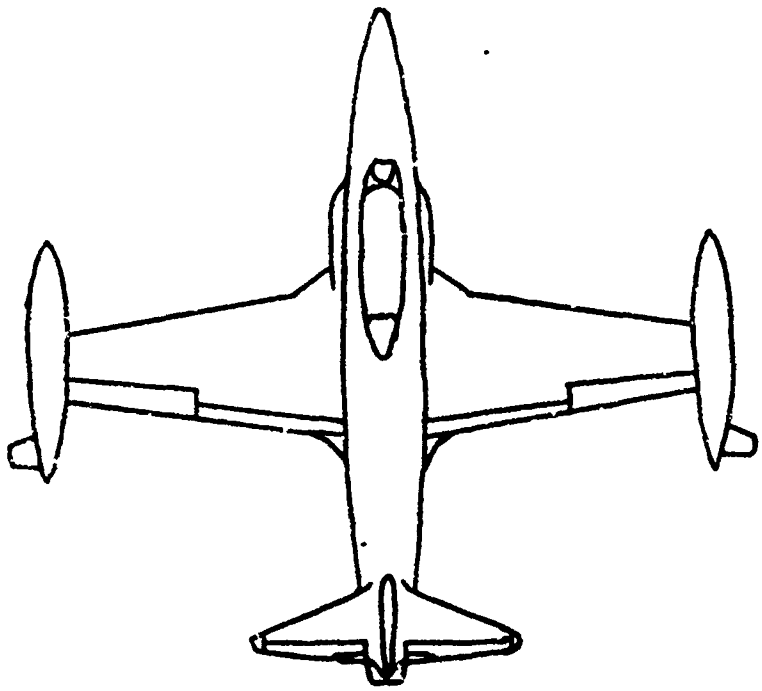
AFFTC-TR-85-19

T-33 (SILVER STAR MK 3) PITOT-STATIC SYSTEM CALIBRATION



AFFTC

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FINAL REPORT

JUNE 1985

AIR FORCE FLIGHT TEST CENTER
EDWARDS AIR FORCE BASE, CALIFORNIA
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE

This technical report, T-33 (Silver Star MK 3) Pitot-Static System Calibration, was submitted under Job Order Number 2591A0 by the Commander, 6510th Test Wing, Edwards AFB, California 93523.

This report has been reviewed by the Office of Public Affairs (AFFTC/PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nationals.

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This report presents the results of pitot-static system calibration tests performed on T-33 (Silver Star MK 3), civil registration number N83TB. The T-33 pitot-static system was calibrated in order to use the T-33 as a pacer for the T-46A pitot-static system calibration tests to be performed during the T-46A Development Test and Evaluation Program. Although the test aircraft will perform satisfactorily as a pacer, ~~however,~~ periodic checks on the pitot-static system's accuracy should be performed. Keywords.

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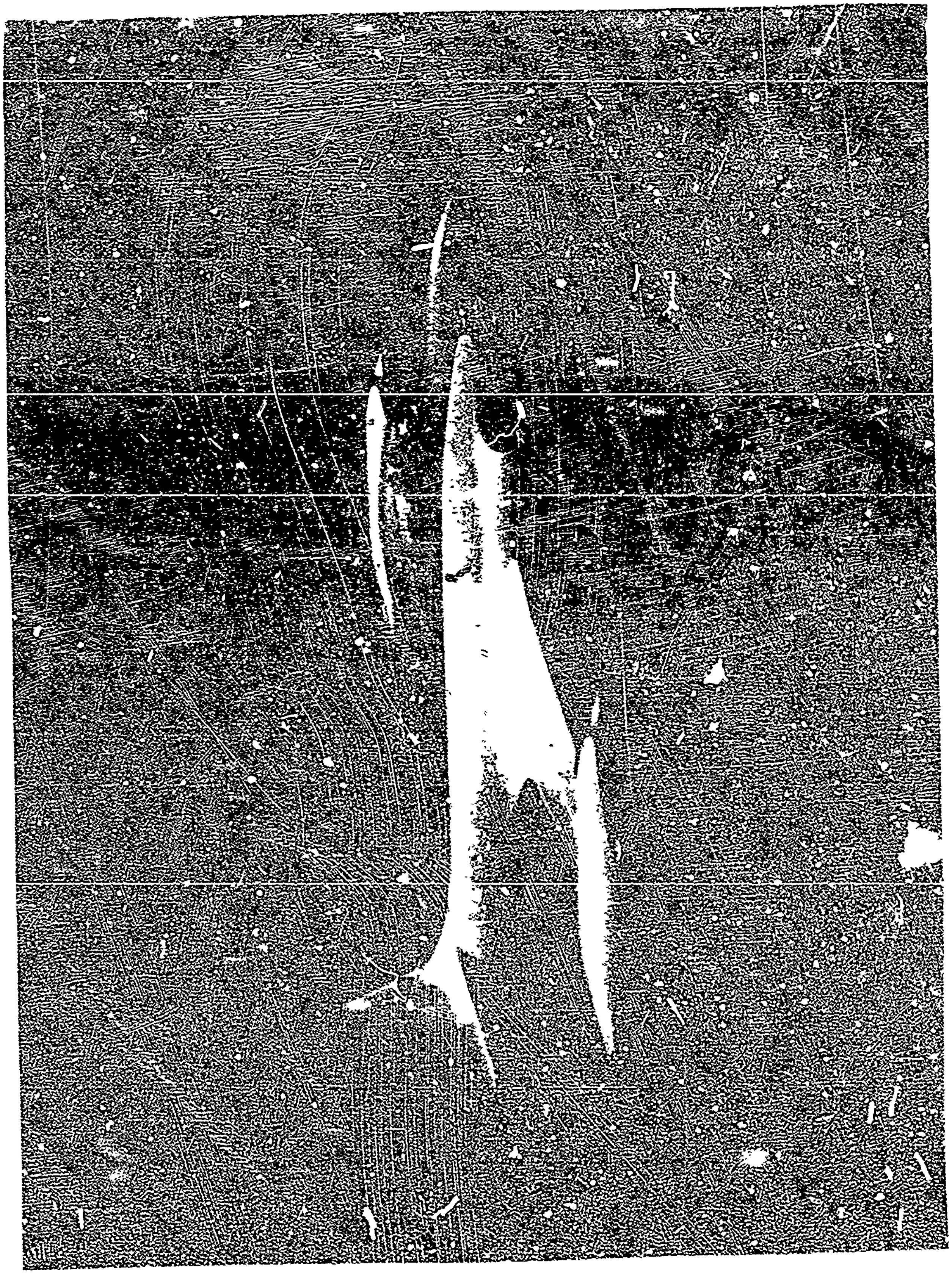
System Calibration

PREFACE

The T-33 (Silver Star MK 3) pitot-static system calibration tests were performed in support of the T-46A Development Test and Evaluation (DT&E) program. The T-46A test program was directed by the T-46A System Program Office (ASD/AFG) of the Aeronautical Systems Division, Wright-Patterson AFB, Ohio. The T-33 pitot-static system calibration was required to enable the T-33 to function as a pacer for the pitot-static system calibration of the T-46A.

The author thanks Mr. Frank Brown and Mr. Al DeAnda for their technical assistance. The project pilots were Major Eric Hansen and Major John Bush of the USAF.



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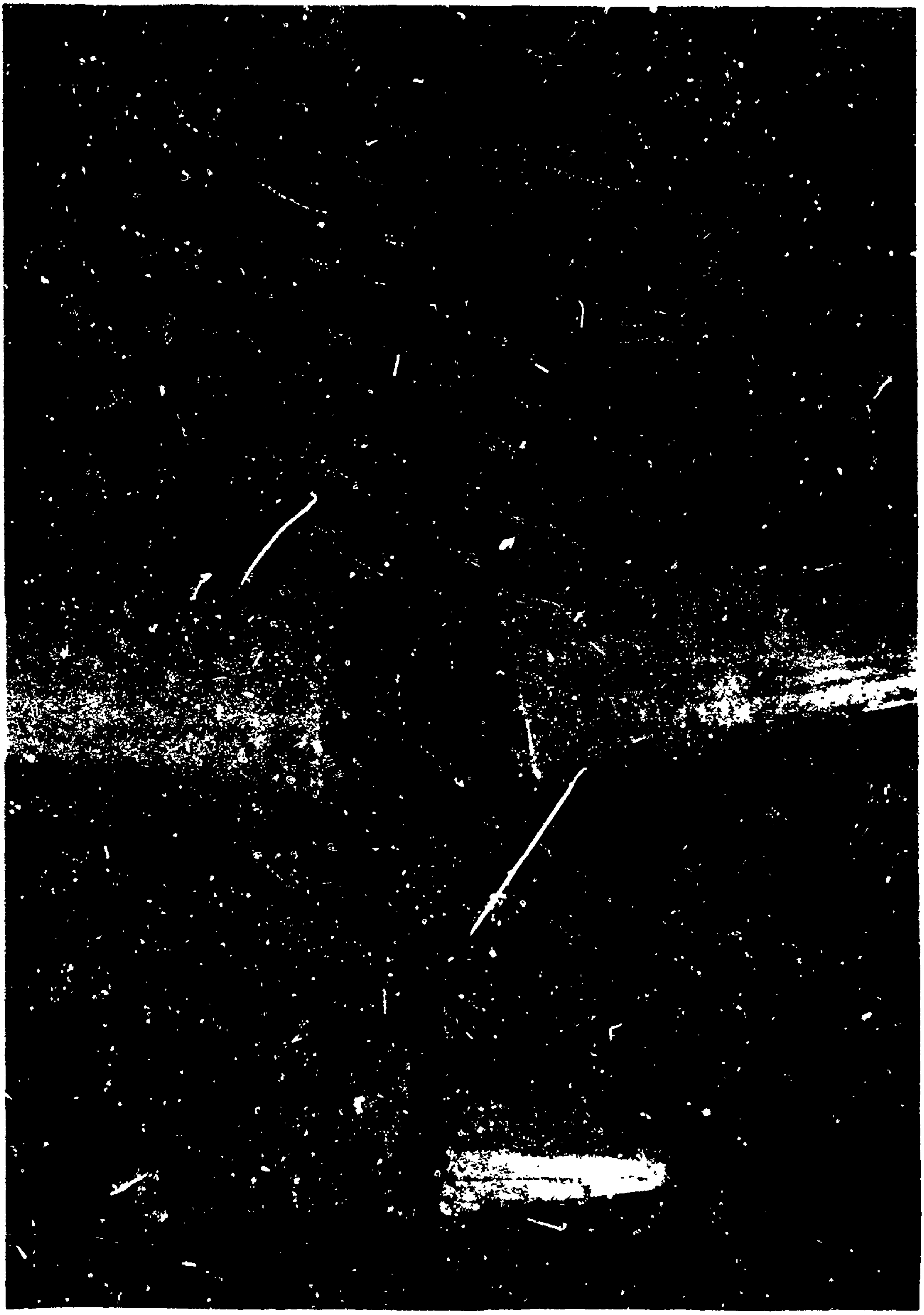

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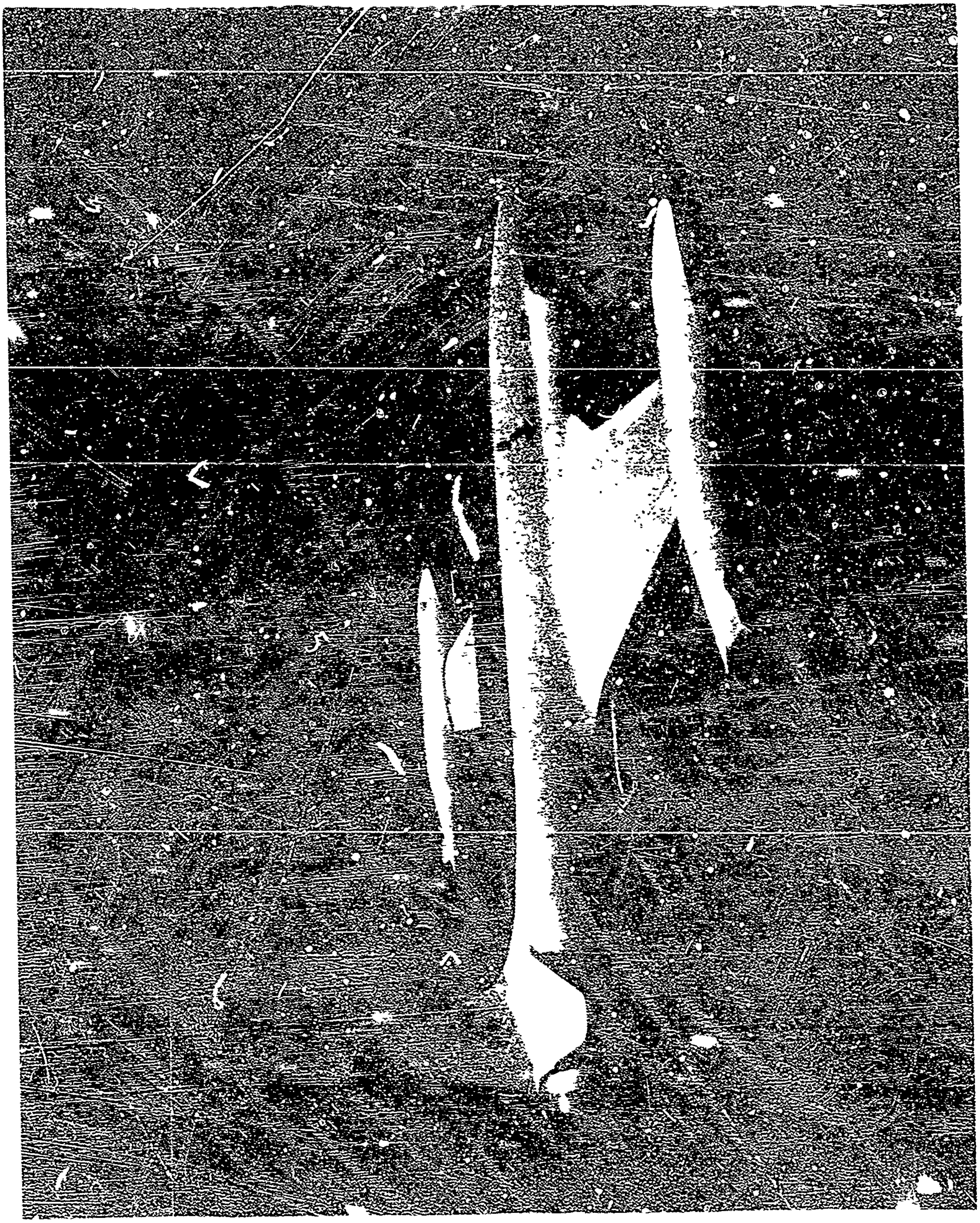


INTRODUCTION

This report presents the results of the T-33 (Silver Star MK 3) pitot-static system calibration tests. The tests were conducted at the Air Force Flight Test Center (AFFTC), Edwards AFB, California in support of the T-46A Development Test and Evaluation (DT&E) Program. The pitot-static system calibration tests were conducted between 17 April 1985 and 15 May 1985 during four sorties totaling 5.2 flight hours.

OBJECTIVE

The objective of this test was to obtain pitot-static system calibration data for the T-33, civil registration N83TB, in order that the aircraft could be used as a pacer in support of the T-46A DT&E Program.

AIRCRAFT DESCRIPTION

The T-33 (Silver Star MK 3) was built by Canadair Ltd., Montreal, Quebec, Canada. The aircraft was owned by Thunderbird Aviation Inc. of Phoenix, Arizona and carried civil registration N83TB. The aircraft was leased by the AFFTC as a support aircraft for the T-46A DT&E Program. The production pitot-static system was used. The system employed a dog-leg pitot probe mounted under the nose on the aircraft centerline approximately 32 inches aft of the nose tip and two static ports symmetrically mounted on the lower sides of the nose approximately 35 inches aft of the nose tip (see Figure 1 and 1A). Calibrated, sensitive airspeed indicators were installed in both cockpits and a calibrated, sensitive altimeter was installed in the rear cockpit.

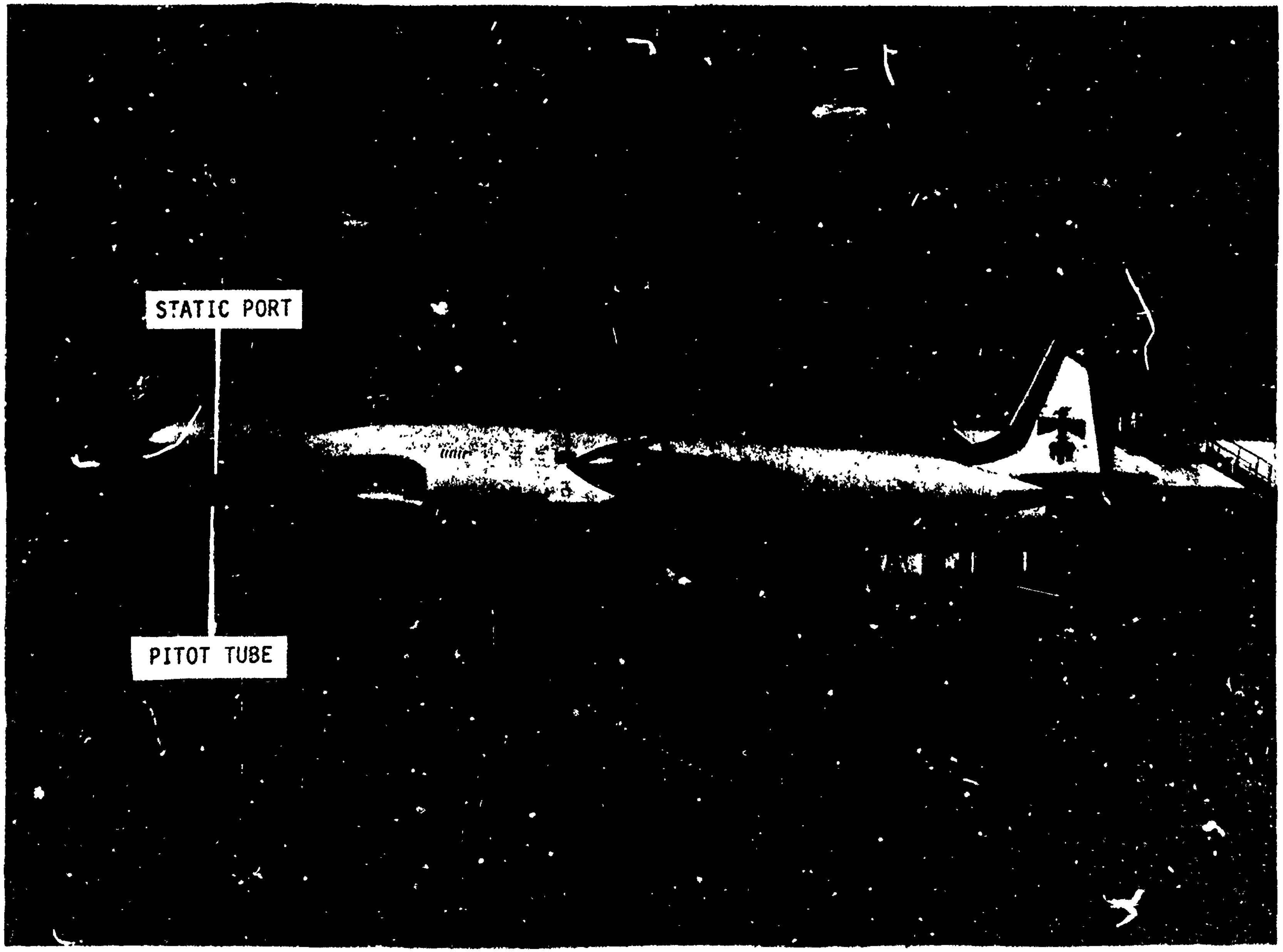


FIGURE 1 PITOT TUBE AND STATIC PORT

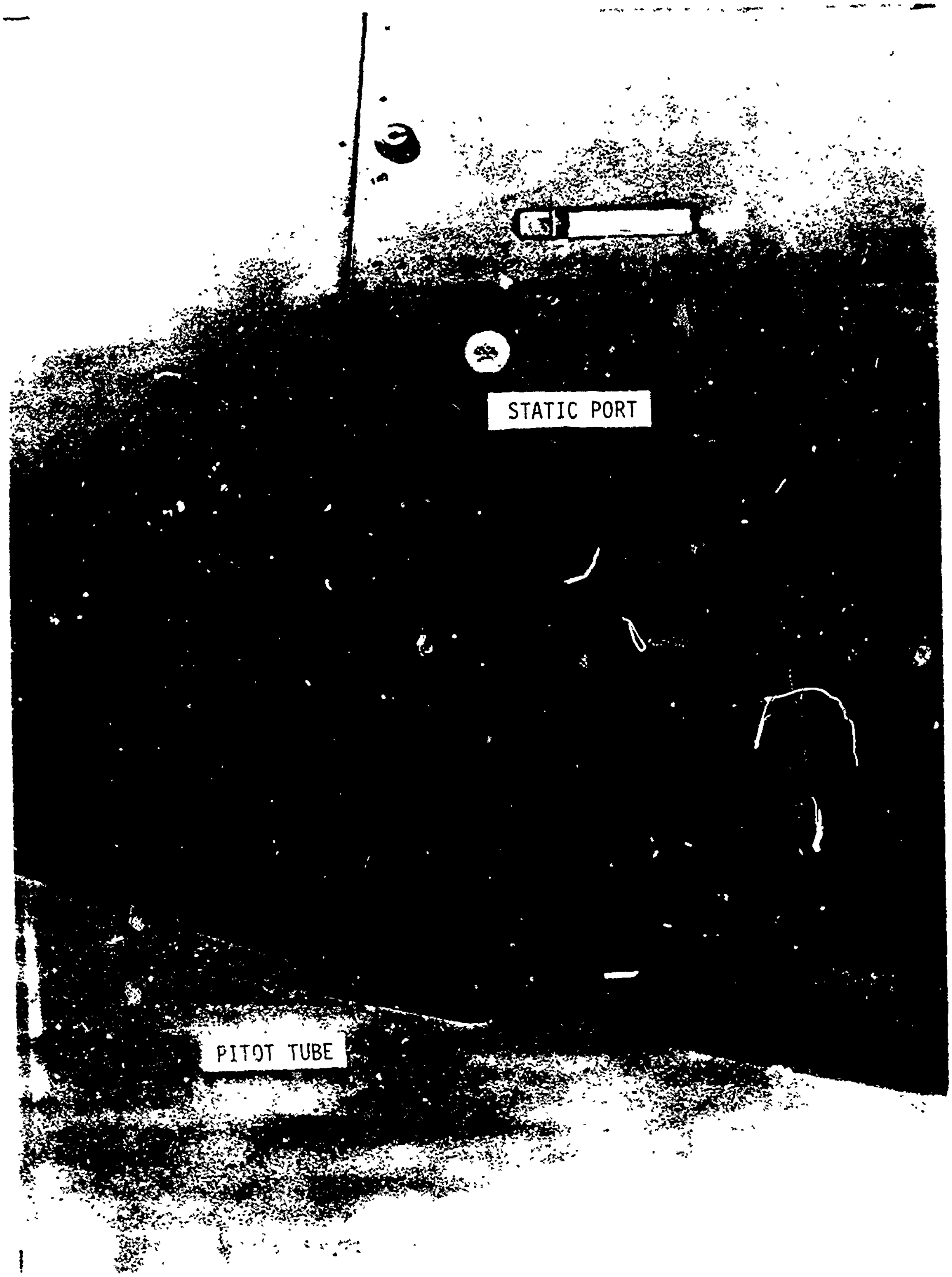
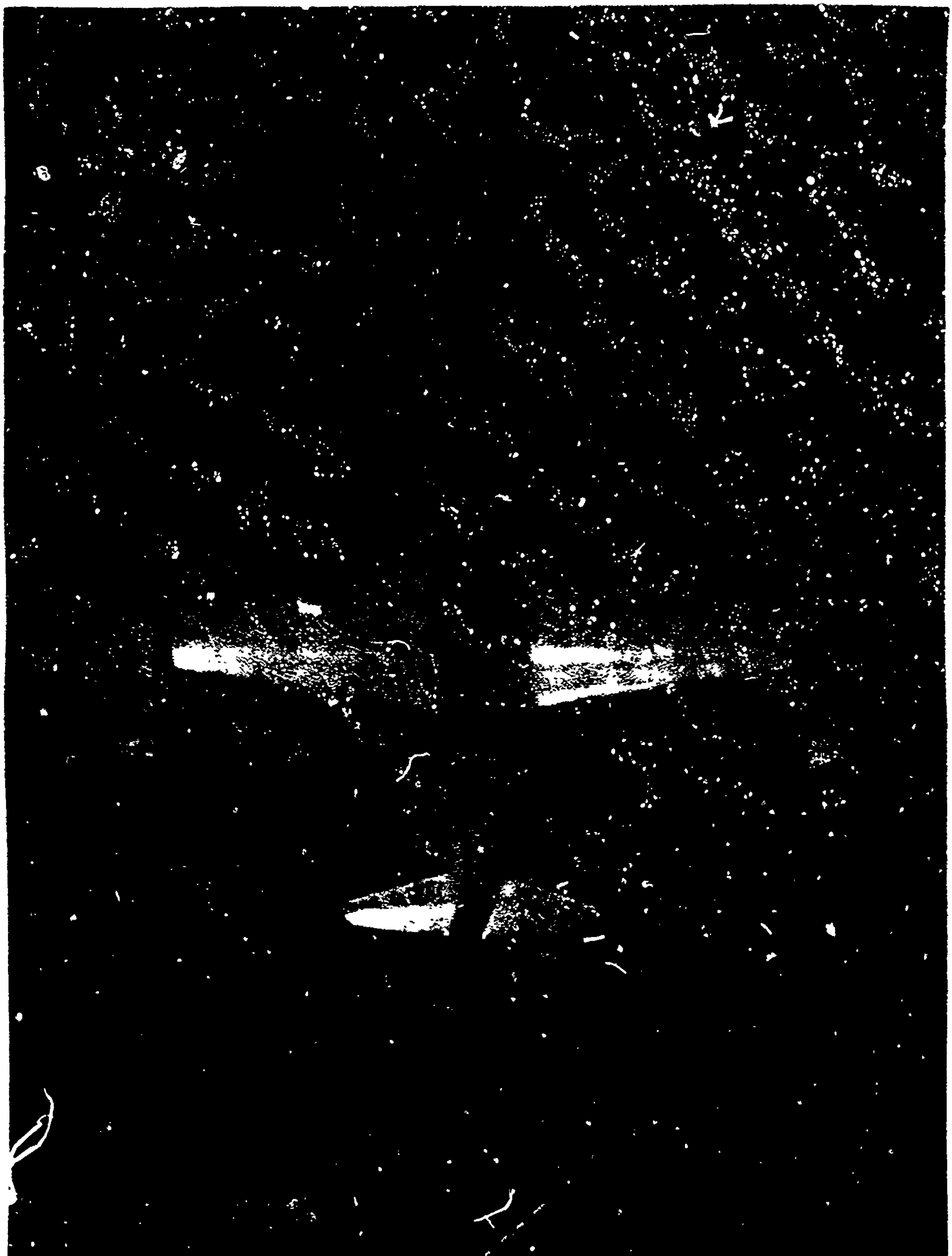


FIGURE 1A PITOT TUBE AND STATIC PORT (DETAIL)



TEST AND EVALUATION

TEST TECHNIQUES

Tower fly-by and pacer data were used to determine the position error. Reference 1 was used as a guideline for the tests. The tower fly-bys were conducted using the AFFTC tower fly-by facility. The position error was obtained from the difference between the T-33 test aircraft's instrument corrected altimeter reading and the aircraft's pressure altitude determined by tower stadiametric observation.

Pacer data was obtained with an AFFTC calibrated pacer aircraft (T-38A, S/N 70-1575). Both stabilized and unstabilized pace techniques were used. During stabilized pace the T-38 pacer flew in close formation with the T-33 test aircraft maintaining the same altitude and airspeed during stabilized straight-and-level flight. The position error was obtained from the difference between the T-33 test aircraft's instrument corrected altimeter reading and the T-38 pacer's instrument and position error corrected altimeter reading.

An unstabilized pace technique was used to obtain data at speeds lower than the T-38 pacer could maintain in stable one-g straight-and-level flight (approximately 170 KCAS). The T-38 pacer set up at the same altitude behind and to the side of the T-33 test aircraft. The T-33 stabilized at the test airspeed (less than 170 KCAS) and the T-38 pacer stabilized at approximately 170 KCAS. Airspeed and altimeter readings were taken as the T-38 pacer overtook the T-33 test aircraft at the same altitude. The position error was obtained from the altimeter difference as with the stabilized pace technique. All data from both aircraft were hand recorded. The front and rear cockpit instrument readings in the pacer and the front and rear test aircraft airspeed readings were each averaged to improve accuracy.

DATA ANALYSIS

The altitude position errors determined from the tests were used for data analysis. Low resolution of the airspeed indicators with respect to the small airspeed position error resulted in large scatter in the position error data determined from the airspeed difference during stabilized pace. Therefore the airspeed difference was not used for analysis. The position error pressure coefficient ($\Delta P_p/q_{cic}$: position error pressure/indicated differential pressure) was calculated from the altitude position error and is shown in Figure 2. The scatter in the low speed data (especially the 20 degree flaps data) was largely due to the degraded accuracy of the unstabilized pace method.

The fairings of Figure 2 were used to develop fairings for Figures 3 through 5. The altitude position error (ΔH_{pc}) determined during the tests is shown in Figure 3. The airspeed position error (ΔV_{pc}) calculated from the altitude position error is shown in Figure 4. The Mach number position error (ΔM_{pc}) calculated from the altitude position error is shown in Figure 5. The data reduction outline is contained in Appendix A.

In order to insure the accuracy of the pitot-static system calibration, periodic checks should be performed. A limited number of tower fly-by passes should be performed periodically to verify the pitot-static system calibration accuracy. (Recommendation 1) The accuracy of the airspeed indicators and altimeters should be checked periodically to insure accurate pitot-static system data. (Recommendation 2)

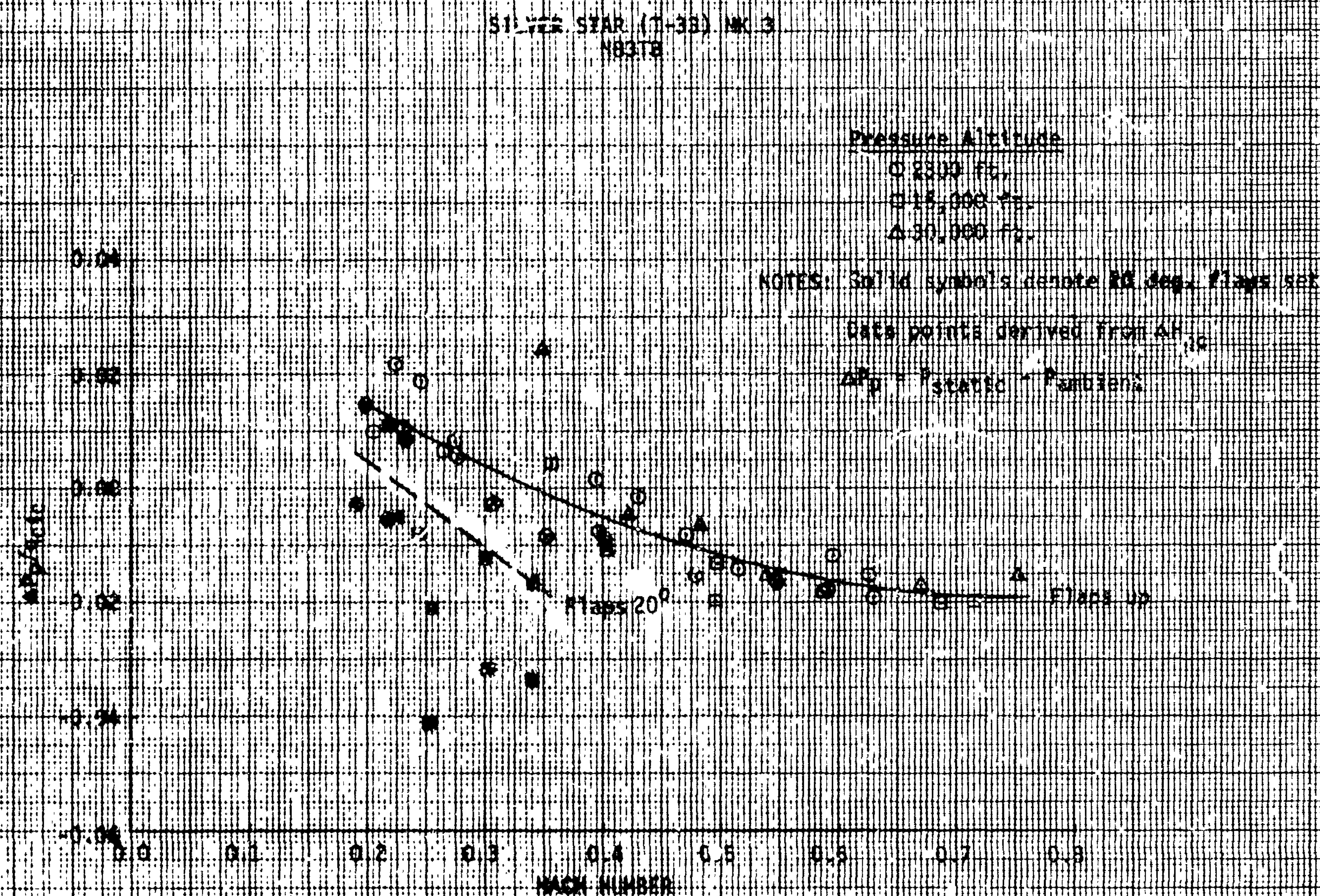


FIGURE 2 POSITION ERROR PRESSURE COEFFICIENT

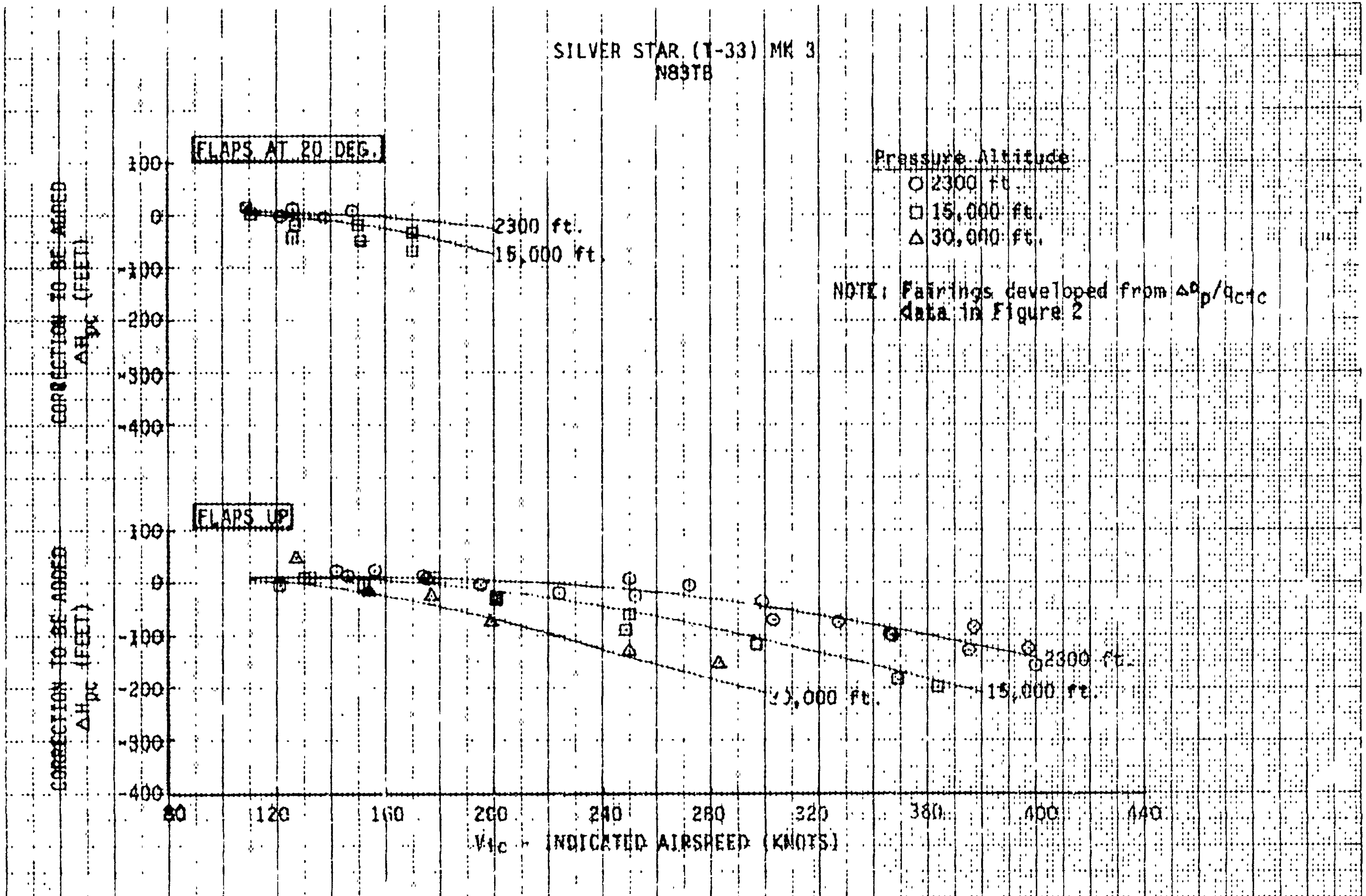


FIGURE 3 ALTITUDE CORRECTION DUE TO POSITION ERROR

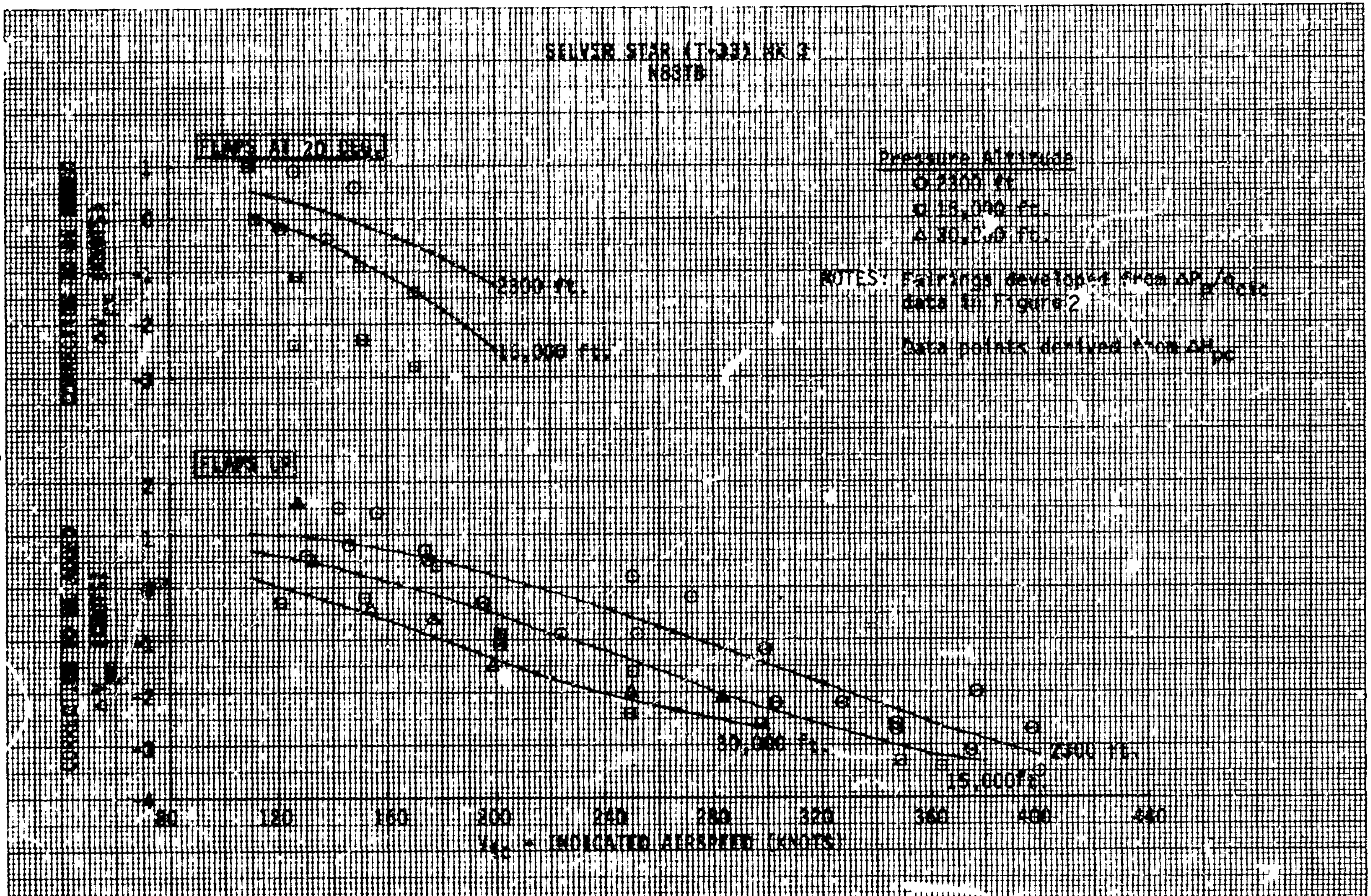


FIGURE 4 AIRSPEED CORRECTION DUE TO POSITION ERROR

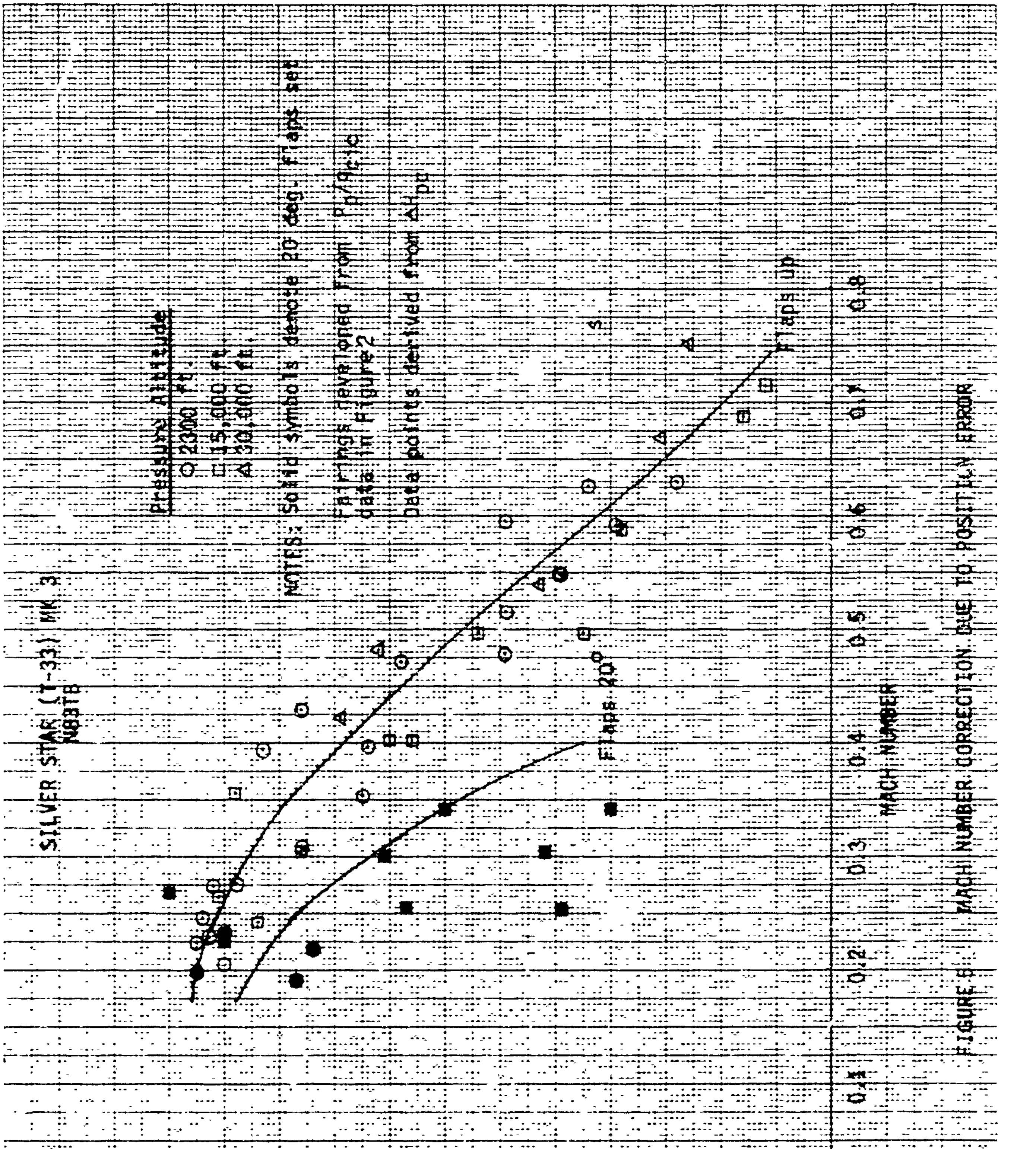


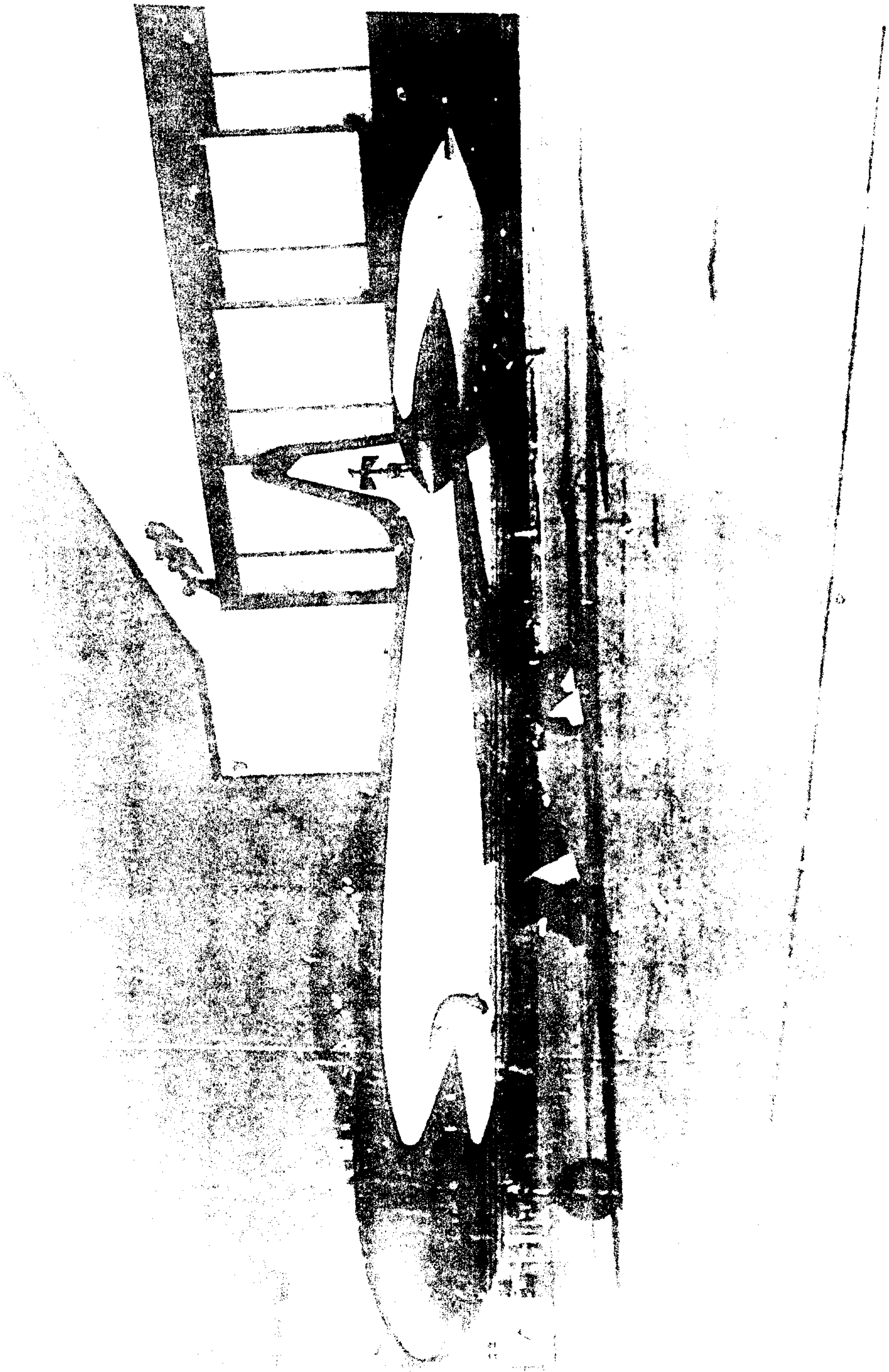
FIGURE 6 MACH NUMBER CORRECTION DUE TO POSITION ERROR

CONCLUSIONS AND RECOMMENDATIONS

Accurate calibration data were obtained for the T-33 (Silver Star MK 3), civil registration N83TB, by the tower fly-by and pacer techniques. The accurate calibration of the pitot-static system will allow the use of the T-33 as a pacer aircraft for support of the T-46A Development Test and Evaluation Program. In order to insure the continued accuracy of the pitot-static system calibration, periodic checks should be performed.

1. A limited number of tower fly-by passes should be performed periodically to verify the pitot-static system accuracy. (page 12)

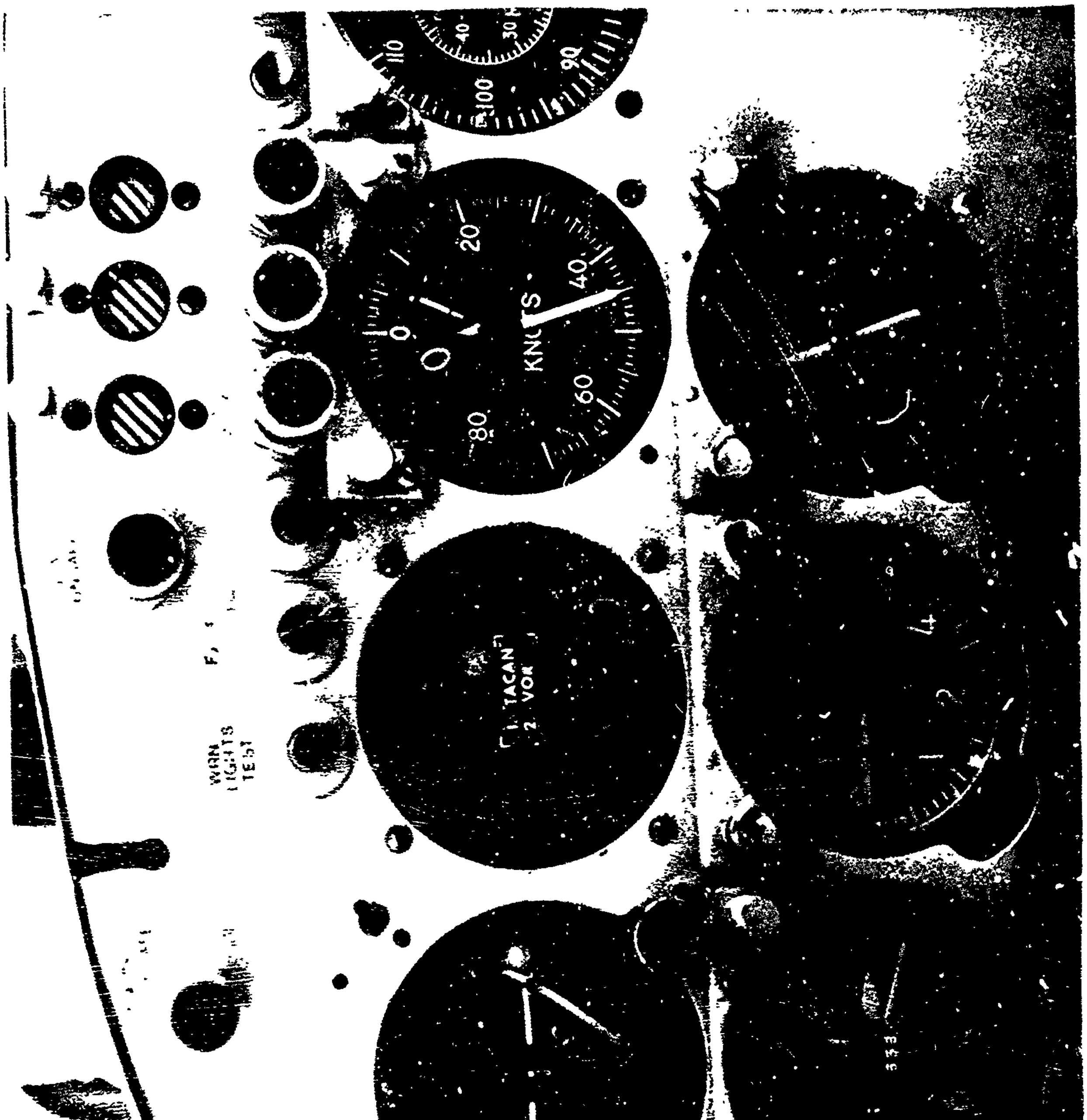
2. The accuracy of the airspeed indicators and altimeters should be checked periodically to insure accurate pitot-static system data. (page 12)



REFERENCES

1. DeAnda, Albert G., AFFTC Standard Airspeed Calibration Procedures, AFFTC-TIH-81-5, Air Force Flight Test Center, Edwards AFB, California, June 1981.

2. Hart, Ronald E., Airspeed Calibration Reduction Program for the Z100 Computer, Office Memo, Air Force Flight Test Center, Edwards AFB, California, September 1984.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TEST

APPENDIX A

DATA REDUCTION OUTLINE

TOWER FLY-BY ANALYSIS

The tower fly-by analysis assumed that the tapeline altitude differences between the ramp, tower and fly-by altitude equaled the equivalent pressure altitude differences. No significant error was introduced by this assumption because of the relatively small altitude differences.

The zero-grid-line pressure altitude (H_y) was determined by the ground block method as follows (see Figure A1):

$$H_y = H_{ic_x} - \Delta h_x + \Delta h_{xy}$$

where: H_{ic_x} = Ground Block Instrument Corrected Altimeter Reading

Δh_x = Height of Altimeter Above Ramp (6 feet)

Δh_{xy} = Height of Tower Eyepiece Above Ramp

The height of the aircraft above the zero-grid-line (Δh_y) was determined as follows:

$$\Delta h_y = K \times G.R.$$

where: K = Geometric Constant (31.5 feet/inch)

G.R. = Grid Reading (inches)

The altitude position error was then calculated:

$$H_{pc} = H_y + \Delta h_y - H_{ic_y}$$

where: H_{ic_y} = Instrument corrected aircraft altimeter reading

Several ground block readings were taken before and after the flight and atmospheric pressure was monitored in the fly-by tower during the tests in order to account for atmospheric pressure variation during the duration of the test flight. No atmospheric pressure variations were observed during the subject tests.

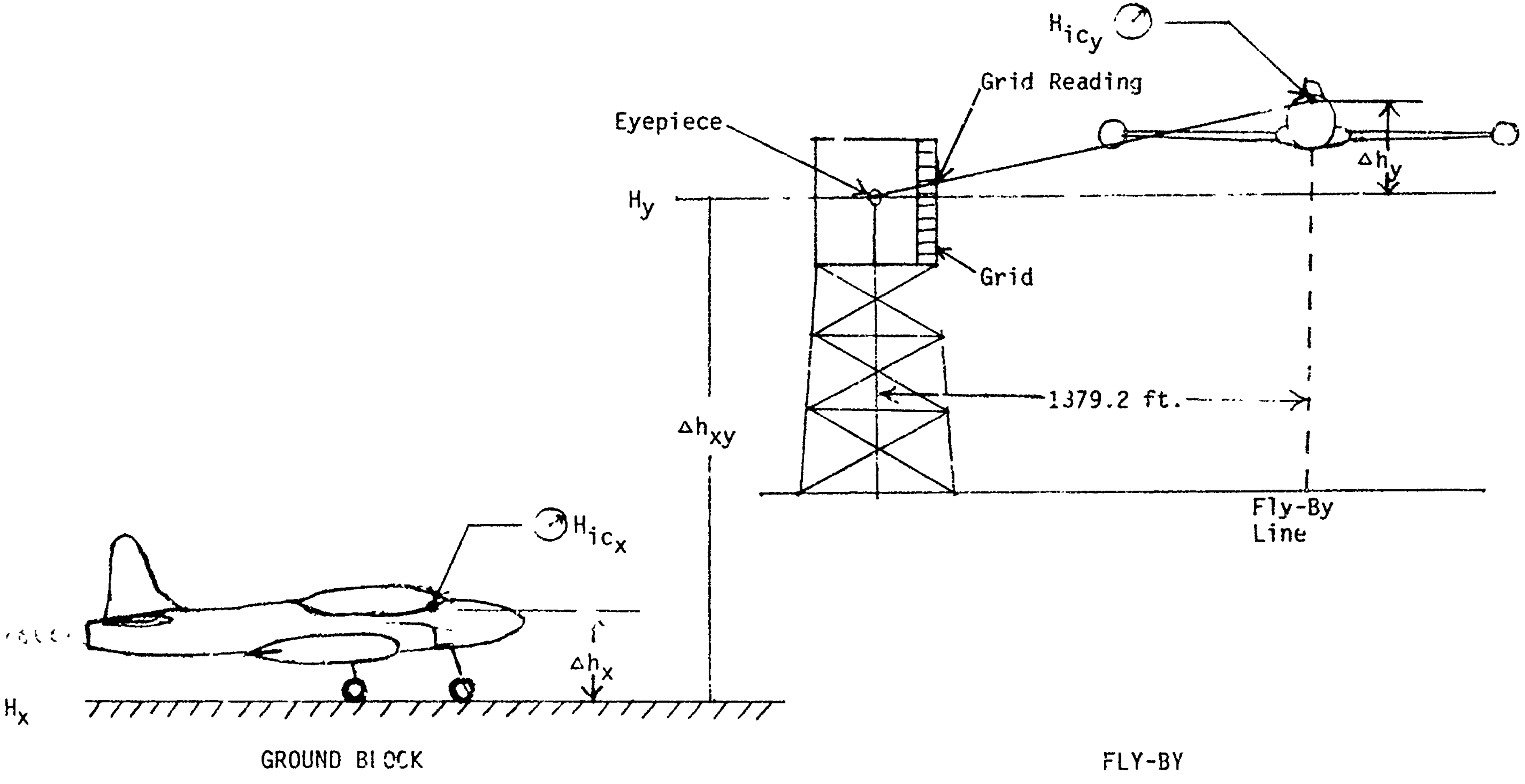

FIGURE A1 TOWER FLY-BY DATA REDUCTION

PACER ANALYSIS

The altitude position error was calculated using the pacer method as follows:

$$\Delta H_{pc} = H_{ic_{test}} - H_{c_{pacer}}$$

where: $H_{ic_{test}}$ = Test aircraft instrument corrected altitude

$H_{c_{pacer}}$ = Pacer aircraft calibrated pressure altitude

The instrument corrections for the T-33 test aircraft's calibrated instruments are shown in Figures A2 through A4.

The equations outlined in Reference 2 were used for subsequent data reduction.

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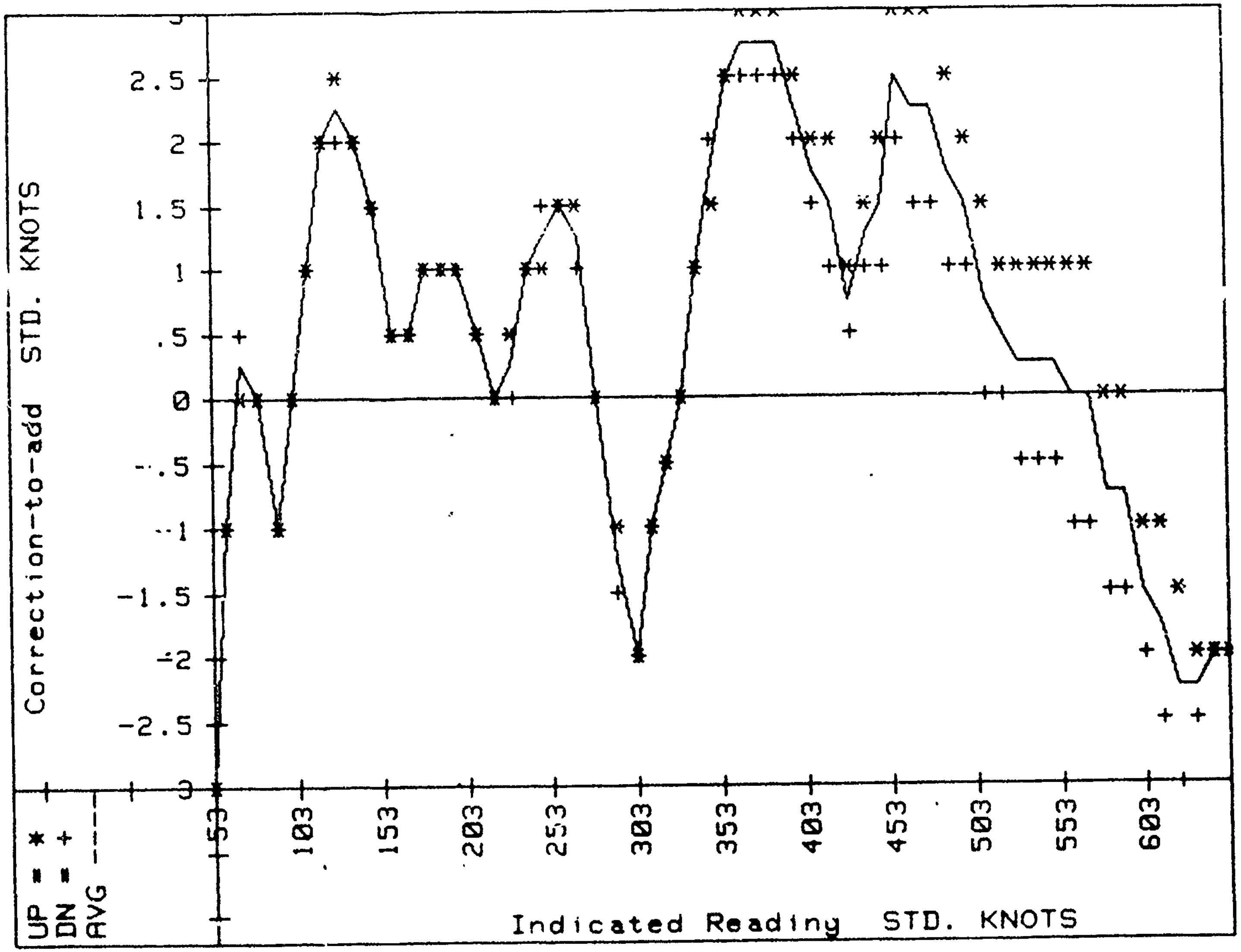

FIGURE A2 FRONT COCKPIT AIRSPEED INSTRUMENT CORRECTION

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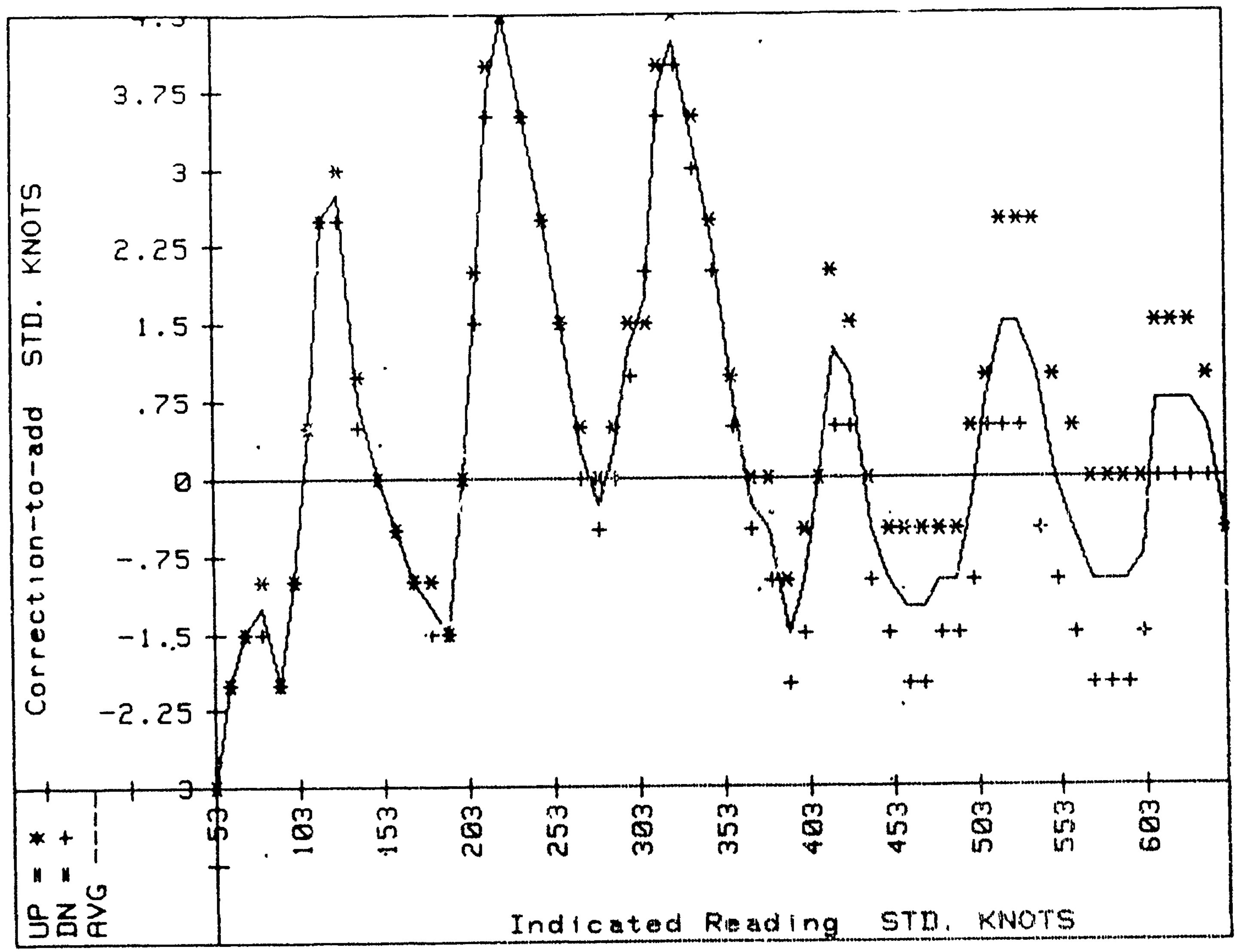


FIGURE A3 REAR COCKPIT AIRSPEED INSTRUMENT CORRECTION

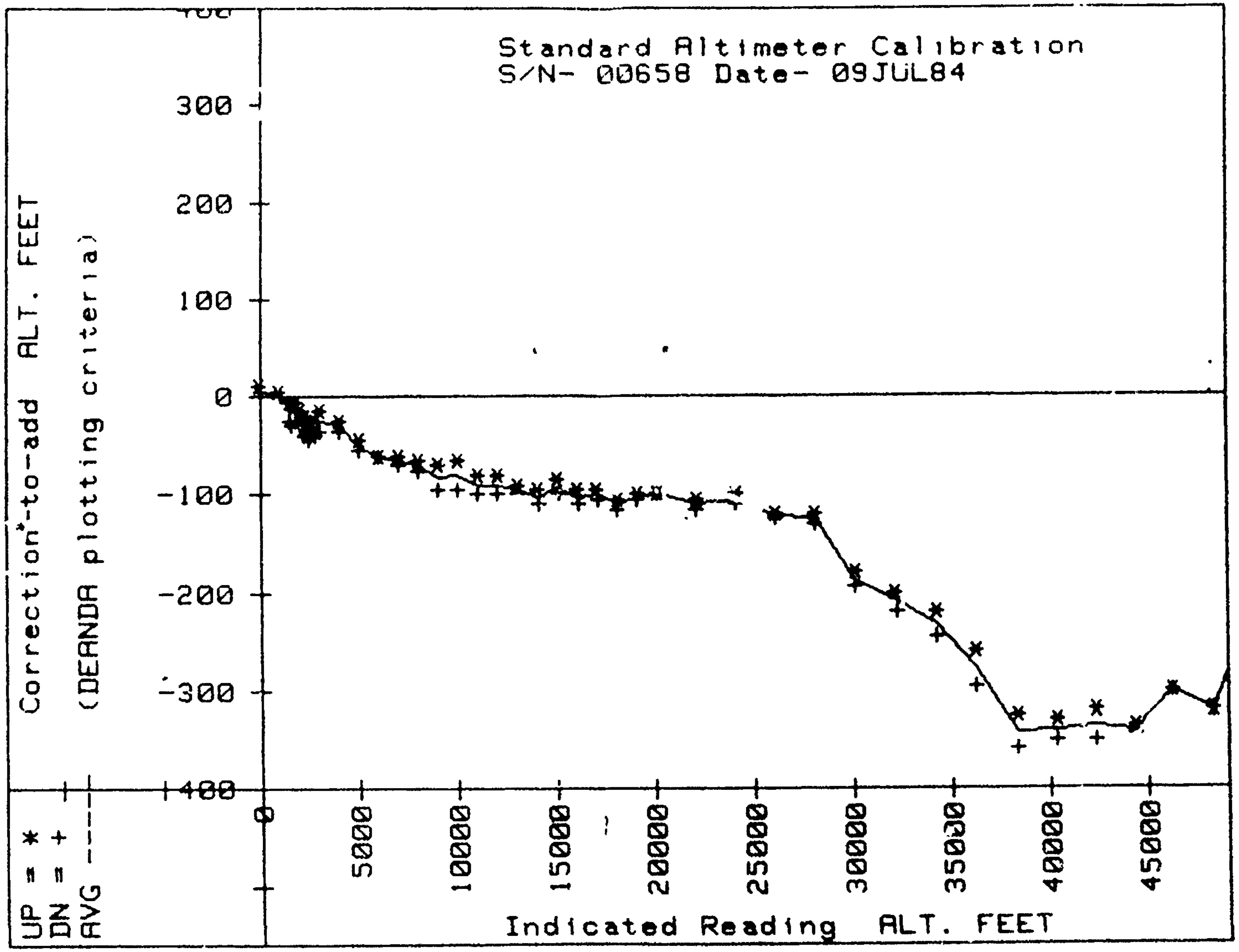
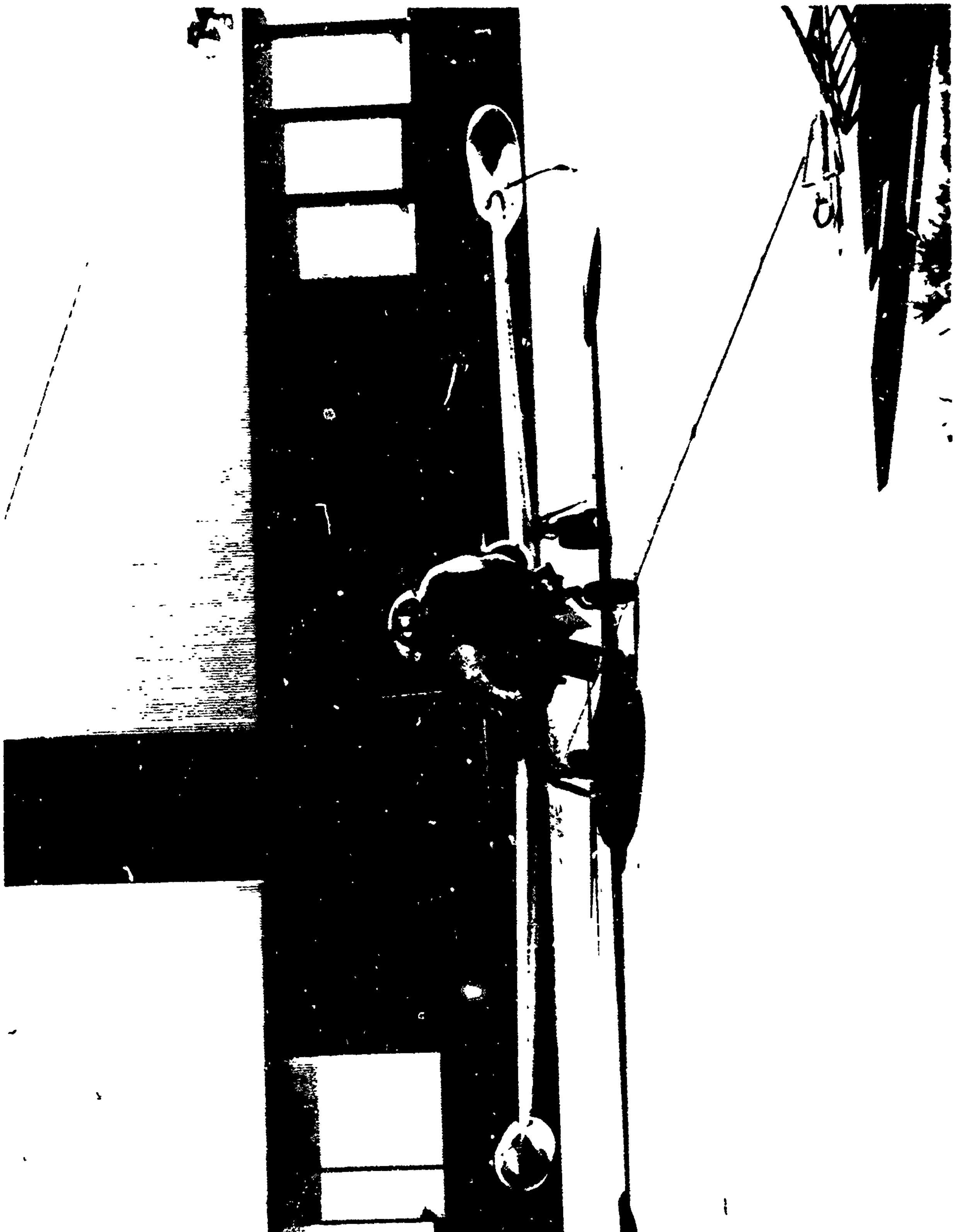


FIGURE A4 REAR COCKPIT ALTIMETER INSTRUMENT CORRECTION

APPENDIX B

FLIGHT LOG

Date	Duration	Crew	Pacer Crew	Test
17 APR 85	1.2 hr	Hansen/Edmondson	---------	Fly-by
18 APR 85	1.4 hr	Bush/Edmondson	---------	Fly-by
14 MAY 85	1.2 hr	Hansen/Woodford	Deehan/Waniczek	Pacer
15 MAY 85	1.4 hr	Hansen/Bjurstrom	Luczak/Woodford	Pacer



LIST OF ABBREVIATIONS AND SYMBOLS

Item	Definitions	Units
AFFTC	Air Force Flight Test Center	----
DT&E	Development Test and Evaluation	----
G.R.	Grid Reading	----
H_c	Pressure Altitude, Calibrated	feet
H_{ic}	Altimeter Reading, Instrument Corrected	feet
H_{ic_x}	Ground Block Altimeter Reading, Instrument Corrected	feet
H_{ic_y}	Fly-By Altimeter Reading, Instrument Corrected	feet
H_x	Ramp Pressure Altitude	feet
H_y	Zero-Grid-Line Pressure Altitude	feet
K	Geometric Constant	feet/inch
KCAS	Knots Calibrated Airspeed	knots
MK	Mark	----
P	Pressure	inches Hg
q_{cic}	Differential Pressure	inches Hg
S/N	Serial Number	----
T	Trainer	----
V_{ic}	Indicated Airspeed, Instrument Corrected	knots
ΔH_{pc}	Altitude Position Error Correction	feet
Δh_x	Height of Altimeter Above Ramp	feet
Δh_{xy}	Height of Tower Eyepiece Above Ramp	feet
Δh_y	Height of Aircraft Above The Zero-Grid-Line	feet
ΔM_{pc}	Mach Number Position Error Correction	----
ΔP_p	Position Error Pressure	inches Hg
ΔV_{pc}	Airspeed Position Error Correction	knots